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# AN EFFECT OF ORIENTATION ON HEAT TRANSFER CHARACTERISTIC FROM TRIANGULAR CYLINDER BY USING WINGLETS

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***ABSTRACT***

***A numerical simulation is performed to study the effect of geothermal orientation of heat transfer and fluid flow characteristic of a triangular cylinder by using two types of winglets (rectangular and curvature) with air flow at the Reynolds number range 10≤Re≤150 and the cylinder heated at a constant temperature. The numerical computations are carried out using FLUENT 6.1 and Navier- Stokes, continuity and energy equations are solved by using SIMPL method with appropriate boundary conditions. The results were agreed with the previous studies, also its shows that the heat transfer will be enhanced from the triangular cylinderby using winglets. Where heat transfer enhanced from triangular cylinder vertex facing the flow with using curvature winglet by 8-30 % and from triangular cylinder base facing the flow with using rectangular winglet by 6-25\ %, also heat transfer increases with increasing Reynolds number.***

***KEYWORDS: CFD, FLUENT, Heat Transfer, Triangular Cylinder & Winglet***

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Original Article

## NOMENCLATURE

| | |
|---|---|
| 2-D | Two dimensions |
| B.C | Boundary condition |
| CFD | Computational fluid dynamic |
| C.V | Control volume |
| CD | Drag coefficient |
| H | Duct height |
| *h* | Length of side wall of cylinder |
| h | Heat transfer coefficient |
| k | thermal conductivity |
| L | Length of duct |
| Nu | Nusselt number |
| Pr | Pr and tl number |
| St | Strault number |
| $s_1$ | Horizontal distance between the vertex and winglet |
| $s_2$ | Vertical distance between the vertex and winglet |
| $S_1$ | $s_1/h$ |
| $S_2$ | $s_2/h$ |

| | |
|---|---|
| T | Temperature |
| u x | Component of velocity |
| v y | Component of velocity |

## 1. INTRODUCTION

Flow around cylinder has been a topic of instance, research for a long time because it uses in the application of heat exchangers and other engineering significance. The optimum design of heat exchanger and other engineering significance can minimize the size of the wake behind a cylinder tube and also improve the heat transfer. Heat transfer from the cylinder can be improved by means of B.L modification with using different shapes of cylinder and addition wings or winglets.

Flow around cylinder have been investigated numerically and experimentally. (Karniadath, G. E 1988) and (Kurdynman, V. U et. Al, 1998), Ref no [1, 2] studied heat transfer from a circular cylinder numerically. (Achenbach, E 1975), Ref no [3] studied heat transfer and B.L separation at high Re. experimentally. Many minimum heat transfer around a circular cylinder occur after separation point. The point of separation around a cylinder moves downstream along surfaces as Reynolds number increase.

(Davis R. W et. al, 1990), Ref no[4] studied plow past rectangular cylinder with $100 \leq Re \leq 2800$, (Tamura T et. al, 1990), Ref no[5] studied 2-D and 3-D flow over square cylinder with different aspect ratio.

(H. Karampour et. al, 2017), Ref no[6] studied the flow around a hexagonal polygon at $Re \leq 200$ numerically with different orientation, the results show that the drag coefficient, Strould number and pressure drop dependent on orientation cylinder.

(S. A. Nada et.al, 2007), Ref no[7] studies fluid flow and heat transfer around semi-cylinder tube in cross flow with different orientation numerically and experimentally at $Re \leq 50000$. The results show that Nu increase with increasing Re and dependent on angle of attract.

The flow over cylinder was studied with a number of researches as (De A.k et. al, 2006), Ref no[ 8] studied laminar flow past triangular cylinder for $10 \leq Re \leq 250$ the result shows that $Re_c = 39.9$,

(Amit Dhiman et. al, 2011), Ref no[9] computationally studied the unsteady flow and heat transfer from a triangular cylinder at $50 \leq Re \leq 150$, where the minimum local Nu at the rear surface of the cylinder. (Zeitoum O et. al, 2011), Ref no[10] investigate 2-D laminar flow past triangular cylinder with two orientations (vertex of triangular cylinder facing the flow and the flat face of triangular cylinder facing the flow)as shown at $1.4 \leq Re \leq 200$.

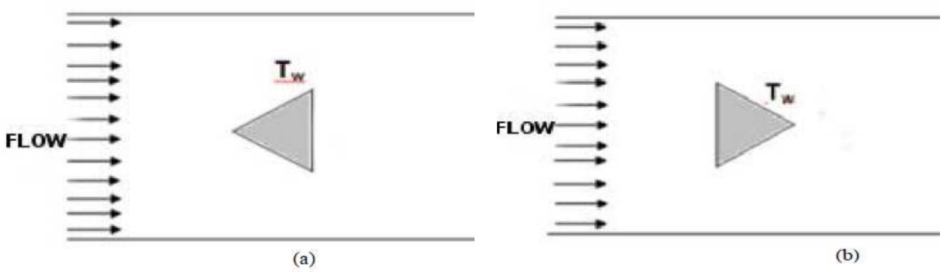



**Figure (1): (a) Vertex Facing the Flow and (b) Base Facing the Flow. (Zeitoum O et. al, 2011), Ref no[10]**

(S.K. Singh et. al, 2015), Ref no[11] studied flow and heat transfer around a triangular cylinder with different orientation atRe ≤200, the results show that the local Nu be maximum at the front area of flow and minimum when the separation occurs, also (De A.k et. al, 2007), Ref no[12] studied the flow and heat transfer around a triangular cylinder with blockage ratio $0.083 \le \beta \le 0.33$ and $80 \le Re \le 200$ with Pr=0.71. The results show that St, CD and Nu variation with β and Re.

(Ahmed Jafari et. al, 2017), Ref no[13] the aim of this study was to simulate the flow around a triangular obstacle in channel numerically at Re=20, 30 and 35. The result shows that Re effect on the flow behind the triangular obstacle where the size of the vortex increases with increasing Re.

(Swam Srikanth, 2010), Ref no[14] this study describes the effects of the blockage ratio on heat transfer and flow across a triangular cylinder placed in channel for $1 \le Re \le 80$ and blockage ratio (0.1, 0.125 and 0.25). The mean drag and Nu are found to increase with an increasing in the blockage ratio also, for fixed Re, the wave length is decreasing with increasing the blockage ratio.

Wings and winglets are used for important heat transfer from the cylinder and many studies done to increase heat transfer from a circular cylinder with using the wing and winglet as (Sohal, M et. al, 2001) Ref no[15], (O'Brien, J. E et. al, 2001) Ref no[16], (Jalal M. Jalil et. al, 2006) Ref no[17] and ( Ehsan Muhseni-Languri et. al, 2008) Ref no[18].

The focus of the present study was to show the effect of a triangular cylinder orientation by using winglets on heat transfer numerically, there are two cases of orientation: -

- The vertex is facing the flow (case 1)
- Base facing the flow (case2)

With two types of winglets

- Rectangular winglets (type 1) using with case 2
- curvature winglets (type 2) using with case 1 as shown in figure 2.

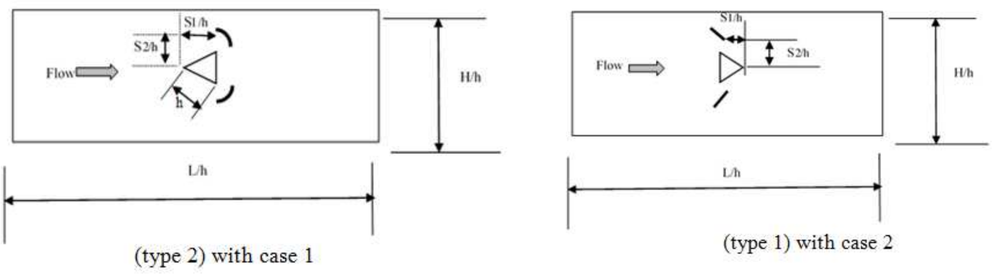



**Figure 2: Triangular Cylinder in Case1with Type 2 and Case2 with Type 1**

Where curvature winglet used with case 2 because of the minimum heat transfer occur behind the triangular cylinder due to generate vortices and using rectangular winglet with case1 because the minimum heat transfer occurs on the inclined surfaces due to generate vortices.

The location of winglet in the case 1and type 2 was $S_1 = s_1/h = (0.75, 0.85 \text{ and } 1)$ with different $S_2 = s_2/h = (0.62, 0.75 \text{ and } 0.85)$ and the location of winglets in the case 2 and type 1 was $S_1 = s_1/h = (0.25, 0.5 \text{ and } 0.75)$ with different $S_2 = s_2/h = (0.5, 0.75 \text{ and } 1)$ all cases at L/h=25 and H/h= 10.

## 2. MATHEMATICAL FORMULATION

A 2-D laminar steady incompressible flow around a triangular cylinder with constant cylinder wall temperature inside wide channel at Re=10-150has been studied.

The governing equation for continuity, momentum and energy equations are (Swam Srikanth, 2010), Ref no[14].

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \qquad (1)$$

x- momentum:-

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\frac{\mu}{\rho}\left[\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right]$$

y- momentum:-

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\frac{\mu}{\rho}\left[\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right] \qquad (2)$$

Energy equation

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{1}{\alpha}\left[\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right] \qquad (3)$$

The convergent criterion of $10^{-6}$ was found sufficiently accurate for this study and the pertinent boundary conditions (B.C) in the simulation are: -

- **Inlet boundary**

  a uniform velocity normal to the inlet with zero normal velocity component

  $u=u_{inlet}$ (4)

  $v=0$

- **Solid Boundary**

  No slip condition for velocity at solid wall channel, cylinder and winglets with constant wall temperature

- **Outlet Boundary**

  The flow at exit is close to fully developed and assumed a zero diffusion flux for all flow variables is used

  $$\frac{\partial u}{\partial x}=0\ \frac{\partial v}{\partial y}=0\ \frac{\partial p}{\partial x}=0 \qquad (5)$$

Fluid flow and heat transfer are solved by using commercial CFD package FLUENT 6.1 with based on C.V technique. The governing equations are solved for all such C.V the package is used to generate the grid as shown in figure 3 the grid was very fine near the cylinder and winglets and a triangle cell were used to construct the grid.

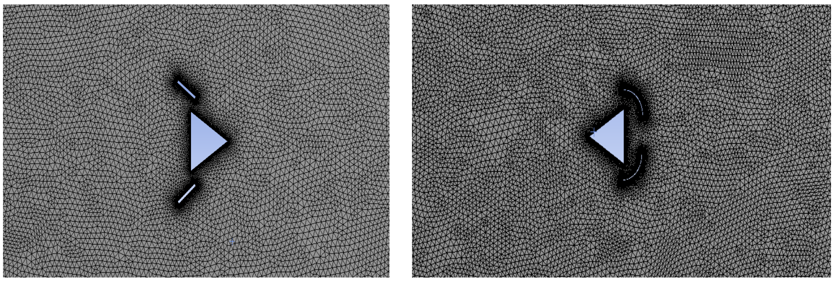


**Figure 3: Grid Generation**

## 3. HEAT TRANSFER AROUND CYLINDER

Nusselt number characterizes the quantitative parameter of heat transfer, the non-dimensional form of local Nu based on the side length of the cylinder (h) is

$$Nu = \frac{h\mathbf{h}}{k} \quad (6)$$

And average Nu from the surface is

$$\text{Nuav}\frac{hav\,\mathbf{h}}{k} = \frac{1}{SA}\int_{SA} Nu\, ds \quad (7)$$

## 4. RESULTS AND DISCUSSIONS

To check the validity of our numerical results with the available results. We have been doing computations for the forced convective flows past a triangular cylinder and compared with other results. Figure 4 compares streamline for the present study with (De A.k et. al, 2006), Ref no [8] at Re=35. The figure shows good agreement with the previous results.

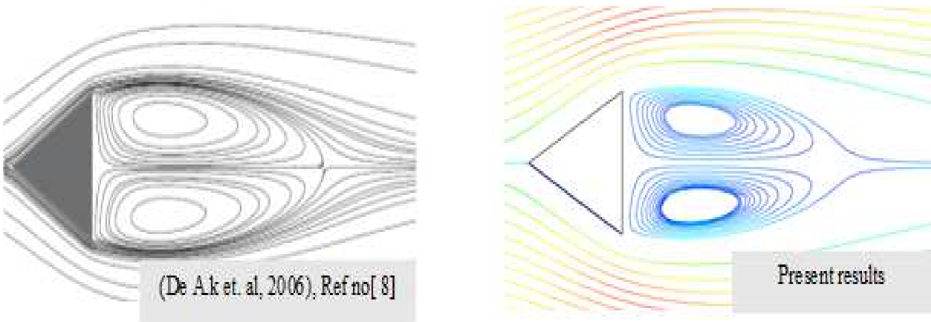



**Figure 4: Streamline Past Triangular Cylinder at Re=35**

Figure 5 compares the local Nusselt number around a triangular cylinder for two cases (a-vertex facing the flow (case 1)) and (b- base facing the flow (case 2)) with. (Zeitoum O et. al, 2011), Ref no[10] at Re=138.8, the results show good agreement with previous results.

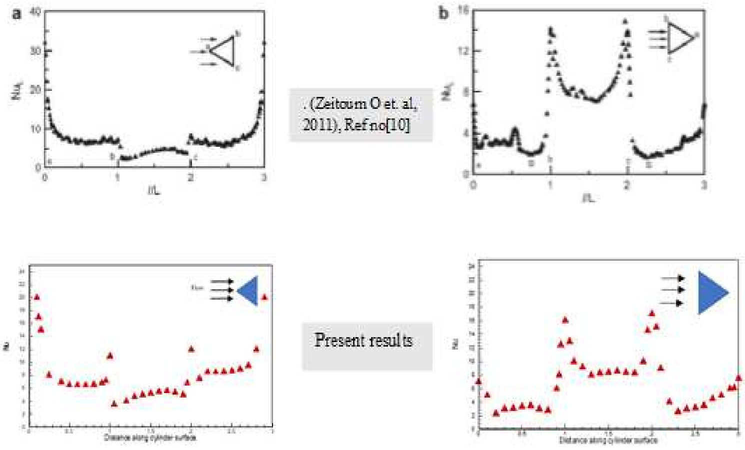



**Figure 5: Local Nusselt Number Over Triangular Cylinder for Case 1 and Case 2 at Re=138.8**

Figure 6 compares the average Nusselt number around a triangular cylinder for vertex facing the flow (case 1) with (Amit Dhiman et. al, 2011), Ref no[9] the results show good agreement.

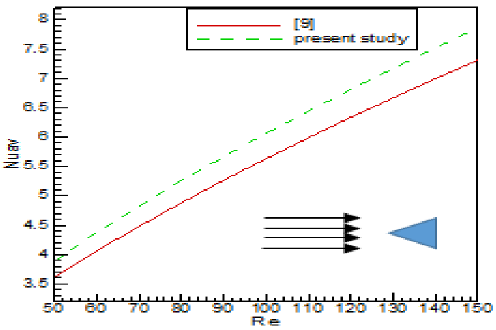



**Figure 6: Average Nusselt Number with Reynolds Number**

Figure 7 shows the temperature, contour over triangular cylinder for case 1 at Re=50 without winglet and by using winglet type 2 at $S_1$=0.75 with different $S_2$. The figures show that maximum temp. Be at the rear of the cylinder, and when using curvature winglets (type 2) The hot zone is limited and reduced by the flow of fluid towards the rear of the cylinder that lead to enhanced heat transfer due to swiping the heat from hot region, the streamline of fluid can be seen in figure 8 where the winglet the flow to change enforced the direction toward the rear of the cylinder. Also, the results show that $S_1$=0.75 and $S_2$=0.75 give maximum heat transfer from the cylinder.

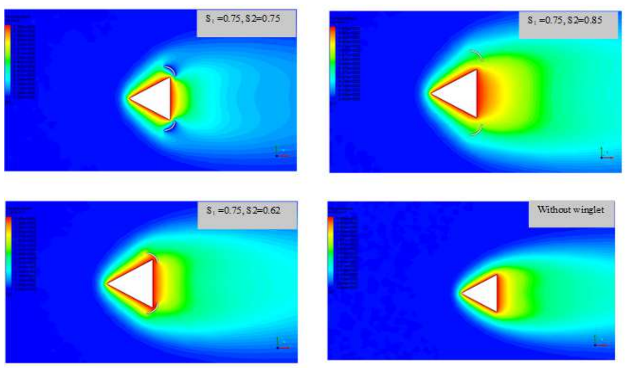



**Figure 7: Temperature Contour over Triangular Cylinder with and without Winglet at Different $S_2$**

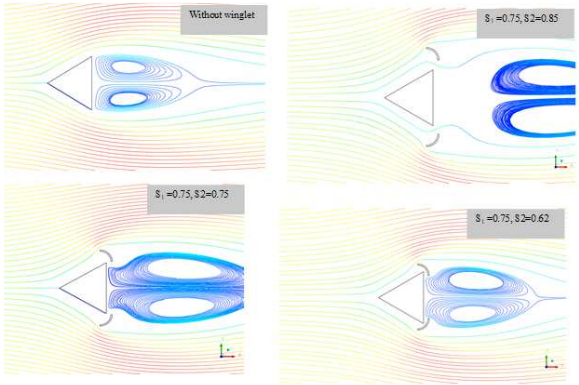


**Figure 8: Streamline over Triangular Cylinder with and without using Curvature Winglets with Different $s_2$**

Figure 9 shows the temperature, contour over triangular cylinder for case 1 at Re=50 without winglet and by using winglet type 2 at $S_2$=0.75 with different $S_1$. The figures show that maximum temperature also is at the rear of the cylinder and when using curvature winglets (type 2) the flow move toward the rear of the cylinder where the flow as shown in the figure 10 (the streamline) swiping the heat and decreasing the hot region. This lead to increasing heat transfer, also the figures show that at $S_1$= 0.85 and $S_2$= 0.75 gives maximum heat transfer.

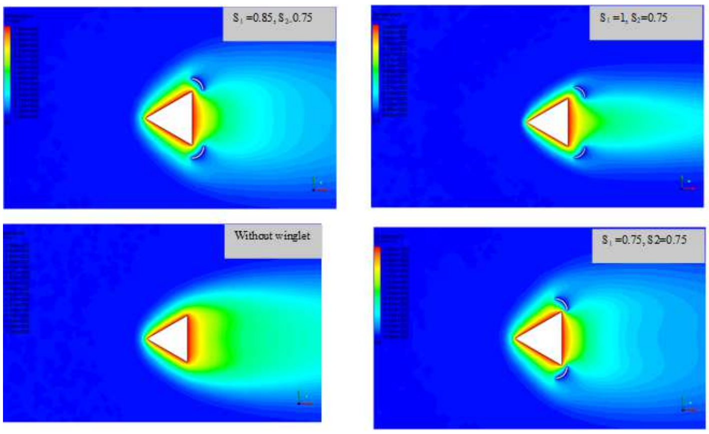


**Figure 9: Temperature Contour over Triangular Cylinder with and without using Curvature Winglets with Different $S_1$**

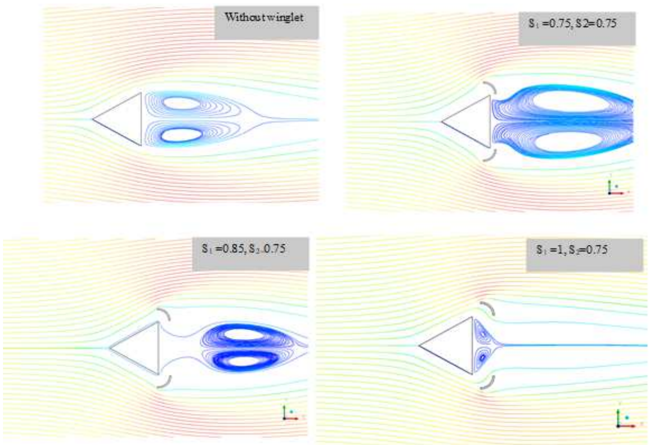


**Figure 10: Streamline Over Triangular Cylinder with and Without using Curvature Winglets with Different $S_1$**

Figure 11, 12 shows temperature contour and streamline over triangular cylinder for case 2 with using rectangular winglet type 1at $S_1$=0.5 with different $S_2$and compares with triangular cylinder without winglets. The minimum heat transfer is on the incline sides and when using winglet leading to moving the flow parallel the cylinder walls and swiping the heat from hot surfaces. The maximum enhanced heat transfer be at $S_1$= 0.5 and $S_2$=0.75, also figures 13, 14 shows temperature contour and streamline over triangular cylinder for case 2 with using rectangular winglet type 1at $S_2$=0.75 with different $S_1$and compares with triangular cylinder without winglets and the maximum heat transfer be at $S_1$=0.5 and $S_2$=0.75

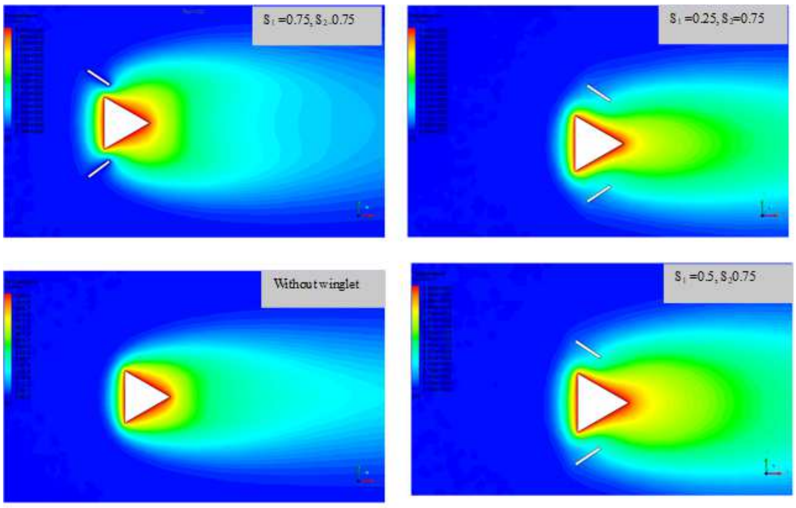



**Figure 11: Temperature Contour Over Triangular Cylinder with and Without using Rectangular Winglets with Different $S_2$**

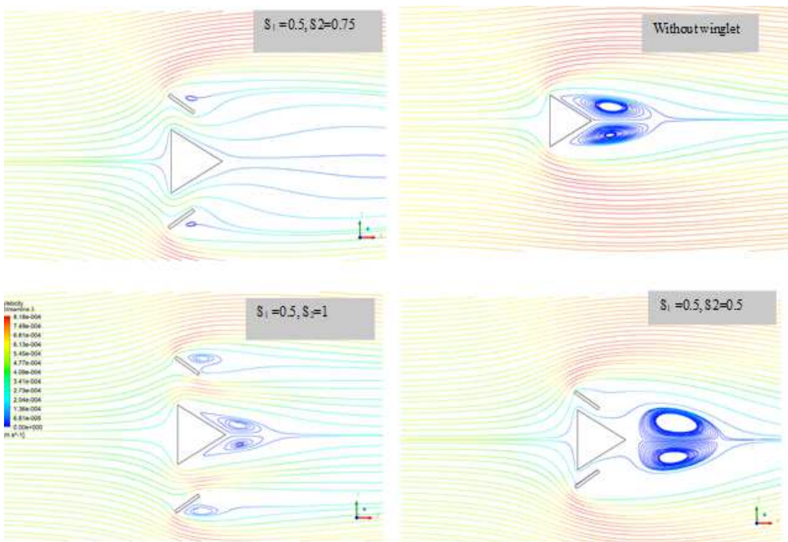



**Figure 12: Streamline Over Triangular Cylinder with and Without using Rectangular Winglets with Different $S_2$**

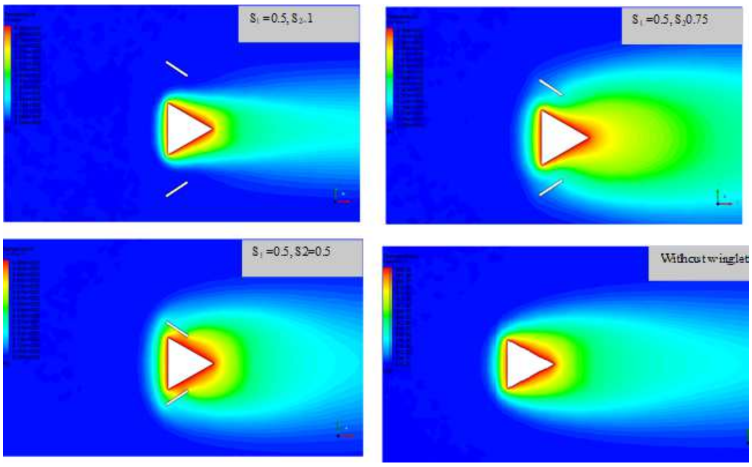



**Figure 13: Temperature Contour over Triangular Cylinder with and Without using Rectangular Winglets with Different $S_1$**

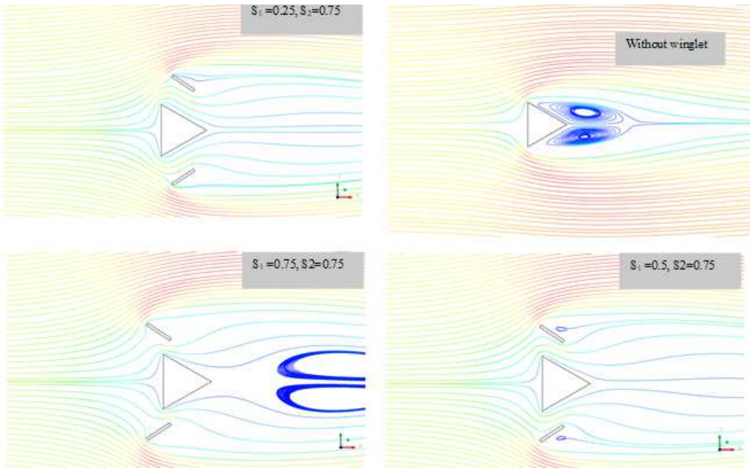
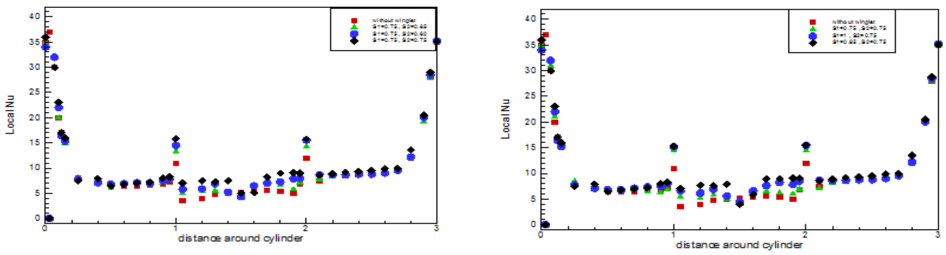



**Figure 14: Streamline Over Triangular Cylinder with and Without using Rectangular Winglets with Different $S_1$**

Figure 15 a, b shows the effect of local Nusselt number over triangular cylinder for case 1 with and without using curvature winglet type 2 at different $S_1$ and $S_2$ respectively. Nusselt number shows increases with using winglets due to enforced the flow to change the direction toward the rear of triangular cylinder the using winglet. The winglet also reduces the volume of vortices behind the cylinder and maximum enhanced heat transfer be at $S_1$ =0.85 and $S_2$=0.75 when changing $S_1$ at constant $S_2$ and maximum enhanced heat transfer be at $S_2$ =0.75 and $S_1$=0.75 when changing $S_2$ at constant $S_1$ respectively.




a b

**Figure 15: Shows Local Nu for Case 1 and Type 2 with Changing the Distances (a) $S_1$ and (b)$S_2$**

Figure 16 a, b shows the effect of local Nu over triangular cylinder for case 2 with and without using curvature winglet type 1 at different $S_1$ and $S_2$ respectively. Also, heat transfer improvement by using winglet due to enforced the flow to change the direction toward the inclined surfaces of triangular cylinder the using winglet. The winglet also removes the eddies away from the surface of the cylinder and maximum enhanced heat transfer is at $S_1$ =0.5 and $S_2$=0.75 when changing $S_1$ at constant $S_2$ and maximum enhanced heat transfer be at $S_2$ =0.75 and $S_1$=0.5 when changing $S_2$ at constant $S_1$ respectively.

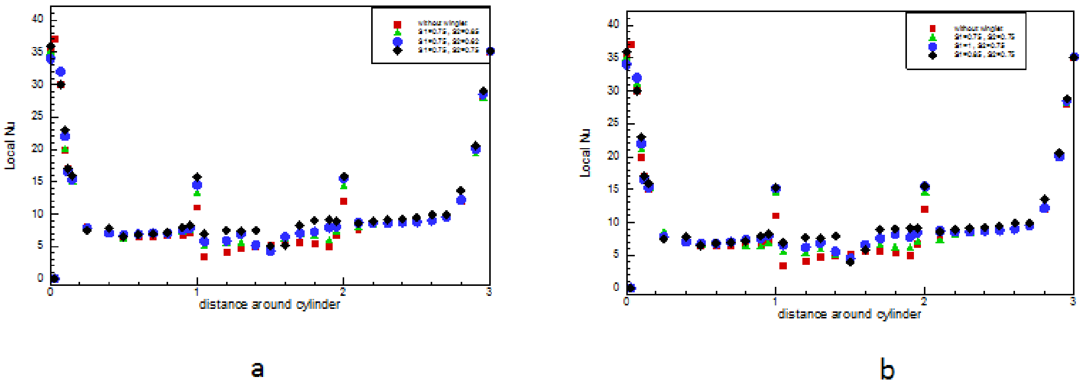



**Figure 16: Shows Local Nu for Case 2 and Type 1 with Changing the Distances (a) $S_1$ and (b) $S_2$**

Figure 17 a, b explains the effect of Re on average Nu for case 2 with and without using curvature winglet type 1 at different $S_1$ and $S_2$ respectively. The results show that average heat transfer increase with increasing Re due to increasing the amount of flow past the surfaces for swiping the heat from cylinder It reveals that $Nu_{av}$ reaching the maximum value at $S_1$=0.85 and $S_2$=0.75 at constant $S_2$. And $S_1$=0.75 and 0.75 at constant $S_1$. Heat transfer enhancement by 8%-30% by using curvature winglet type 1 with case 2.

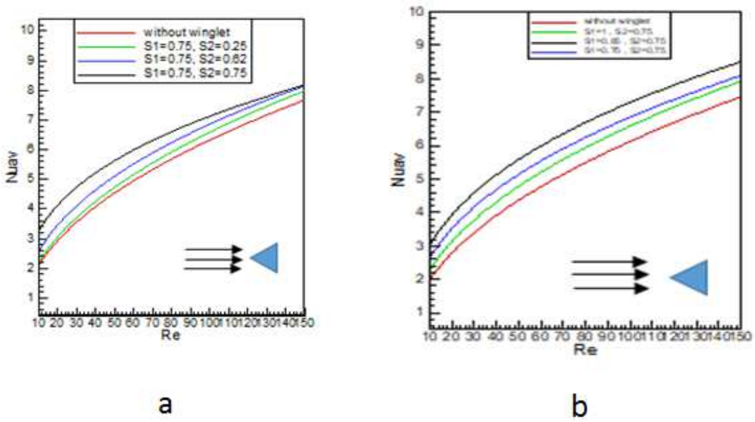



**Figure 17: Average Nusselt Number with Reynolds Number for case 1with Winglet Type 2 at different $S_1$ (a) and Different $S_2$ (b)**

Figure 18 a, b explains the effect of Re on average Nu for case 1 with and without using rectangular winglet type 2 at different $S_1$ and $S_2$ respectively. The results show that average heat transfer increase with increasing Re due to increasing the amount of flow past the surfaces for swiping the heat from cylinder. It reveals that $Nu_{av}$ reaching the maximum value at $S_1$=0.5 and $S_2$=0.75 at constant $S_2$. Also $S_1$=0.5 and 0.75 at constant $S_1$. Heat transfer enhancement by 6%-25% by using rectangular winglet type 2 with case 1.

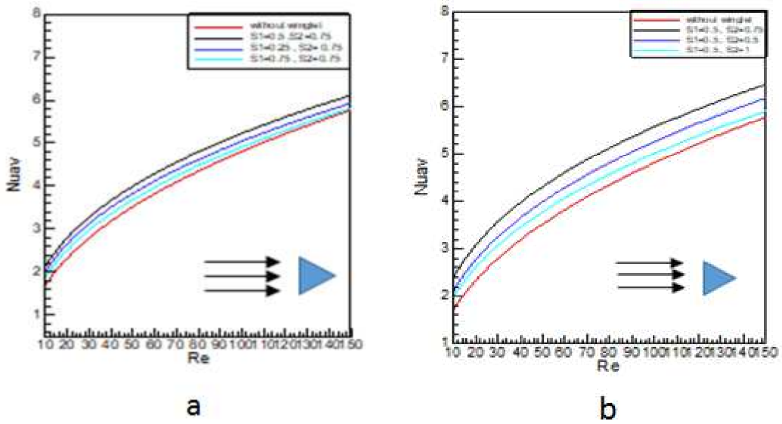



**Figure 18: Average Nusselt Number with Reynolds Number for case 2 with Winglet Type 1 at different $S_1$ (a) and Different $S_2$ (b)**

## 5. CONCLUSIONS

- The 2-D steady flow and force convection heat transfer over triangular cylinder. In this study using two types of winglets with triangular cylinder (curvature winglet type 1) with (vertex facing the flow case 1) and (rectangular winglet type2) with (base facing the flow case2).
- Using winglet improvement heat transfer from triangular cylinder due to decreasing vortices behind the cylinder (case 1) and swiping the heat from the surfaces of triangular cylinder (case 2).
- Heat transfer increases with increasing Reynolds number.
- There is an effect on the location of winglets forenhanced heat transfer, where maximum heat transfer is at $S_1$=0.85 and $S_2$=0.75 at constant $S_2$. And $S_1$=0.75 and 0.75 at constant $S_1$ at case 1 and for $S_1$=0.5 and $S_2$=0.75 at constant $S_2$. Also $S_1$=0.5 and 0.75 at constant $S_1$ fore case 2.
- Maximum heat transfer was 8%-30% by using curvature winglet type 1 with case 2. And was 6%-25% by using rectangular winglet type 2 with case 1.

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